

THERMONUCLEAR FUSION²⁶

Natural abundance of isotopes:

hydrogen	$n_D/n_H = 1.5 \times 10^{-4}$
helium	$n_{He^3}/n_{He^4} = 1.3 \times 10^{-6}$
lithium	$n_{Li^6}/n_{Li^7} = 0.08$

Mass ratios:	$m_e/m_D = 2.72 \times 10^{-4} = 1/3670$
	$(m_e/m_D)^{1/2} = 1.65 \times 10^{-2} = 1/60.6$
	$m_e/m_T = 1.82 \times 10^{-4} = 1/5496$
	$(m_e/m_T)^{1/2} = 1.35 \times 10^{-2} = 1/74.1$

Absorbed radiation dose is measured in rads: 1 rad = 10^2 erg g⁻¹. The curie (abbreviated Ci) is a measure of radioactivity: 1 curie = 3.7×10^{10} counts sec⁻¹.

Fusion reactions (branching ratios are correct for energies near the cross section peaks; a negative yield means the reaction is endothermic):²⁷

- (1a) D + D $\xrightarrow[50\%]{}$ T(1.01 MeV) + p(3.02 MeV)
- (1b) $\xrightarrow[50\%]{}$ He³(0.82 MeV) + n(2.45 MeV)
- (2) D + T \longrightarrow He⁴(3.5 MeV) + n(14.1 MeV)
- (3) D + He³ \longrightarrow He⁴(3.6 MeV) + p(14.7 MeV)
- (4) T + T \longrightarrow He⁴ + 2n + 11.3 MeV
- (5a) He³ + T $\xrightarrow[51\%]{}$ He⁴ + p + n + 12.1 MeV
- (5b) $\xrightarrow[43\%]{}$ He⁴(4.8 MeV) + D(9.5 MeV)
- (5c) $\xrightarrow[6\%]{}$ He⁵(2.4 MeV) + p(11.9 MeV)
- (6) p + Li⁶ \longrightarrow He⁴(1.7 MeV) + He³(2.3 MeV)
- (7a) p + Li⁷ $\xrightarrow[20\%]{}$ 2 He⁴ + 17.3 MeV
- (7b) $\xrightarrow[80\%]{}$ Be⁷ + n - 1.6 MeV
- (8) D + Li⁶ \longrightarrow 2He⁴ + 22.4 MeV
- (9) p + B¹¹ \longrightarrow 3 He⁴ + 8.7 MeV
- (10) n + Li⁶ \longrightarrow He⁴(2.1 MeV) + T(2.7 MeV)

The total cross section in barns (1 barn = 10^{-24} cm²) as a function of E, the energy in keV of the incident particle [the first ion on the left side of Eqs. (1)–(5)], assuming the target ion at rest, can be fitted by²⁸

$$\sigma_T(E) = \frac{A_5 + [(A_4 - A_3 E)^2 + 1]^{-1} A_2}{E [\exp(A_1 E^{-1/2}) - 1]}$$

where the Duane coefficients A_j for the principle fusion reactions are as follows:

	D-D (1a)	D-D (1b)	D-T (2)	D-He ³ (3)	T-T (4)	T-He ³ (5a-c)
A_1	46.097	47.88	45.95	89.27	38.39	123.1
A_2	372	482	50200	25900	448	11250
A_3	4.36×10^{-4}	3.08×10^{-4}	1.368×10^{-2}	3.98×10^{-3}	1.02×10^{-3}	0
A_4	1.220	1.177	1.076	1.297	2.09	0
A_5	0	0	409	647	0	0

Reaction rates $\bar{\sigma}v$ (in $\text{cm}^3 \text{sec}^{-1}$), averaged over Maxwellian distributions:

Temperature (keV)	D-D (1a + 1b)	D-T (2)	D-He ³ (3)	T-T (4)	T-He ³ (5a-c)
1.0	1.5×10^{-22}	5.5×10^{-21}	10^{-26}	3.3×10^{-22}	10^{-28}
2.0	5.4×10^{-21}	2.6×10^{-19}	1.4×10^{-23}	7.1×10^{-21}	10^{-25}
5.0	1.8×10^{-19}	1.3×10^{-17}	6.7×10^{-21}	1.4×10^{-19}	2.1×10^{-22}
10.0	1.2×10^{-18}	1.1×10^{-16}	2.3×10^{-19}	7.2×10^{-19}	1.2×10^{-20}
20.0	5.2×10^{-18}	4.2×10^{-16}	3.8×10^{-18}	2.5×10^{-18}	2.6×10^{-19}
50.0	2.1×10^{-17}	8.7×10^{-16}	5.4×10^{-17}	8.7×10^{-18}	5.3×10^{-18}
100.0	4.5×10^{-17}	8.5×10^{-16}	1.6×10^{-16}	1.9×10^{-17}	2.7×10^{-17}
200.0	8.8×10^{-17}	6.3×10^{-16}	2.4×10^{-16}	4.2×10^{-17}	9.2×10^{-17}
500.0	1.8×10^{-16}	3.7×10^{-16}	2.3×10^{-16}	8.4×10^{-17}	2.9×10^{-16}
1000.0	2.2×10^{-16}	2.7×10^{-16}	1.8×10^{-16}	8.0×10^{-17}	5.2×10^{-16}

For low energies ($T \lesssim 25$ keV) the data may be represented by

$$(\bar{\sigma}v)_{DD} = 2.33 \times 10^{-14} T^{-2/3} \exp(-18.76T^{-1/3}) \text{ cm}^3 \text{ sec}^{-1};$$

$$(\bar{\sigma}v)_{DT} = 3.68 \times 10^{-12} T^{-2/3} \exp(-19.94T^{-1/3}) \text{ cm}^3 \text{ sec}^{-1},$$

where T is measured in keV.

The power density released in the form of charged particles is

$$P_{DD} = 3.3 \times 10^{-13} n_D^2 (\bar{\sigma}v)_{DD} \text{ watt cm}^{-3} \text{ (including the subsequent D-T reaction);}$$

$$P_{DT} = 5.6 \times 10^{-13} n_D n_T (\bar{\sigma}v)_{DT} \text{ watt cm}^{-3};$$

$$P_{D\text{He}^3} = 2.9 \times 10^{-12} n_D n_{\text{He}^3} (\bar{\sigma}v)_{D\text{He}^3} \text{ watt cm}^{-3}.$$